Intrinsic Channel Properties, Scattering Mechanisms, Quantum Transport Properties in Transition Metal Dichalcogenides

by

Kraig Andrews

DISSERTATION

Submitted to the Graduate School

of Wayne State University

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

2008

MAJOR: Physics

Approved by:

_____
Advisor

_____

_____

_____

Table of Contents

List of Figures

List of Tables

List of Symbols

Symbol	Description	Unit
$\mathbf{A}$	vector potential	$\mathrm{V\,s\,m^{-1}}$
A	area	$\mathrm{cm^2}$
B	magnetic field	T
C	capacitance	F
E	electric field	$\mathrm{V\,m^{-1}}$
E	energy	eV (J)
E_F	Fermi energy	eV
E_g	bandgap energy	eV
$\hat{\mathbf{H}}$	Hamiltonian	eV (joule)
I	current	A
I_ds	drain current	A
L	length	µm
L	channel length	µm
m	mass	kg
$m^\star$	effective mass	kg
n	carrier density	$\mathrm{cm^{-2}}$
n	charge carrier density	$\mathrm{C\,cm^{-2}}$
$\hat{\mathbf{p}}$	momentum operator	$\mathrm{kg\,m\,s^{-1}}$
R	resistance	$\mathrm{k\Omega\,\mu m}$ (Ω)
R_c	contact resistance	$\mathrm{k\Omega\,\mu m}$
R_H	Hall coefficient	$\mathrm{m^3\,C^{-1}}$
$\hat{\mathbf{s}}$	spin operator	$\hbar$ (J s)
T	temperature	K

V	voltage	V
V_{bg}	backgate voltage	V
V_{ds}	drain voltage	V
V_{H}	Hall voltage	V
w	channel width	µm
μ	magnetic moment	$\mathrm{eV\,T^{-1}}$
μ	mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
μ_e	electron mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
μ_{FE}	field-effect mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
μ_{H}	Hall mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
μ_p	hole mobility	$\mathrm{cm^2\,V^{-1}\,s^{-1}}$
ρ	resistivity	$\Omega\,\mathrm{cm}$
ρ_{xx}	longitudinal resistivity	Ω
ρ_{xy}	transverse resistivity	Ω
σ	conductivity	µS
σ_{xx}	longitudinal conductivity	µS
σ_{xy}	transverse conductivity	µS
τ	scattering time	s
τ_{q}	quantum scattering time	s
Φ_{B}	barrier height	eV
$\Phi_{\mathrm{B}n}$	electron barrier height	eV
$\Phi_{\mathrm{B}p}$	hole barrier height	eV
Φ_M	metal work function	eV
Φ_S	semiconductor work function	eV
χ	electron affinity	eV
χ_S	semiconductor electron affinity	eV
ω_c	cyclotron frequency	Hz

List of Physical Constants

Symbol	**Quantity**	**Value**
k_{B}	Boltzmann's constant	$1.380\,66 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
		$8.617\,34 \times 10^{-5}\,\mathrm{eV\,K^{-1}}$
ϵ_0	dielectric constant	$8.854\,18 \times 10^{-12}\,\mathrm{A^2\,s^4\,kg^{-1}\,m^{-3}}$
e	elementary charge	$1.602\,18 \times 10^{-19}\,\mathrm{C}$
eV	electron volt	$1.602\,18 \times 10^{-19}\,\mathrm{J}$
c	speed of light	$2.997\,92 \times 10^{8}\,\mathrm{m\,s^{-1}}$
h	Planck's constant	$6.626\,07 \times 10^{-34}\,\mathrm{J\,s}$
$\hbar$	reduced Planck's constant	$1.054\,57 \times 10^{-34}\,\mathrm{J\,s}$ $(h/2\pi)$
$R_{\mathrm{K-90}}$	von Klitzing constant	$25\,812.807\,455\,55\,\Omega$
m_e	electron mass	$9.109\,383 \times 10^{-31}\,\mathrm{kg}$
$k_{\mathrm{B}}T$	Thermal energy	$0.025\,86\,\mathrm{eV}$ $(T = 27^{\circ}\mathrm{C})$
		$0.025\,26\,\mathrm{eV}$ $(T = 20^{\circ}\mathrm{C})$
μ_B	Bohr magneton	$9.274\,009 \times 10^{-24}\,\mathrm{J\,T^{-1}}$
		$5.788\,381 \times 10^{-5}\,\mathrm{eV\,T^{-1}}$
		$e\hbar/2m_e$ (atomic units)

Source: CODATA Recommened Values of the Fundamental Physics Constants: 2014, Mohr *et al.*[1]

Acronyms

SB Schottky barrier

References

[1] PJ Mohr, DB Newell, and BN Taylor. Codata recommended values of the fundamental constants 2014,(2015). *arXiv preprint arXiv:1507.07956*, 2015.